

# The Basic Requirements for the Development of Efficient Applications for E-Learning

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**Abstract**—The article is devoted to the creation of applications for e-learning, the elements of which are implemented in the educational process of many universities of the Russian Federation, describes the problems that arise and demonstrates possible ways to overcome them. The authors share many years of experience in the development and use in the educational process of applications made in the form of a set of web documents using CSS, HTML and Java Script technologies. The article discusses as the methodological requirements for such applications, and so their format, which should correspond to the specifics of the electronic devices used. The main requirements that should be taken into account in the development of applications are given: both for the user's convenience – the principles of usability, and for the implementation of the main tasks of training: the presentation of theoretical material, the development of skills in solving practical problems and the control of the level of knowledge gained by trainees. The paper demonstrates the electronic educational complexes in English and mathematics, which were developed by the authors on the basis of their own original shells (templates) and are used in the educational process of the St. Petersburg state Marine Technical University and the Mozhaiskiy Military Space Academy. The effectiveness of their application and methods of increasing efficiency are discussed.

**Keywords**—*distant education, e-learning, electronic educational complex, mathematics, English grammar, usability principles, educational materials, interface, electronic textbooks*

## I. INTRODUCTION

The term “E-Learning” (e-Learning) is currently understood as a system of learning based on the use of modern information and electronic technologies. According to the United Nations Educational Scientific and Cultural Organization (UNESCO) specialists “e-learning” is understood as learning through the Internet and multimedia”.

Despite the widespread use of electronic (computers and

laptops) and wireless mobile devices (tablets and smartphones) in modern students, the use of e-learning elements in universities of the Russian Federation is not common, while 77% of American universities online courses were included in the educational process in 2015. The limited spread of e-learning in Russia is obviously a consequence of the inertia and conservatism of teachers, as students tend to be very active and involved in this process with great interest. Such inertia of higher school teachers is very regrettable, because the learning process using online courses is effective and interesting for full-time and distance learning (blended learning), as it allows you to use: the possibility of the Internet for the exchange of information between students and the teacher; access of students to the teaching materials of the discipline at a convenient time and anywhere; rational sequence of studying the discipline in any volume and with the actual depth; the ability to control the level of mastery of the educational material.

Use in educational process of elements of e-learning creates a digital learning environment, which can be implemented such modern pedagogical technologies of blended learning as a “flipped classroom” (flipped classroom) [5] or the system of distant education, MOOC (massive open online course), i.e. massive open online course [15].

Technology “inverted class” differs from traditional technologies in that students first work on their own new material, and then discuss it with the teacher. This significantly improves the quality of the educational process, as it allows not only to work out the skills and problem solving skills in practice, but also to discuss with the teacher the theoretical material independently studied by students, all this creates conditions for the co – creation of the teacher and students [12], in which the role of the teacher and student - “sender and active recipient of new information” can change. Co-creation promotes both more efficient use of educational time and creative development of both sides of the educational process.

MOOC is a promising distance education technology

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that is used in startups such as:

Coursera (<http://www.coursera.org/>);

Udacity (<https://www.udacity.com/>);

edX (<https://www.edx.org/>);

and NovoED (<https://novoed.com/>).

The video lectures are mostly in English, and the video lectures presented on Coursera in Russian are mainly related to the humanities.

The use of e-learning in the educational process should ensure the integration of information and pedagogical technologies, while the technology of information transfer from teacher to student (group of students) is an auxiliary environment for the organization of educational activities [18].

## II. IMPLEMENTATION OF E-LEARNING (E-LEARNING) IN HIGHER EDUCATION

The aim set by the authors is to study the possibility and effectiveness of the use of elements of e-learning in the mixed (full-time-distance) educational process, as well as the format developed for this software application, providing convenience and ease of use.

The use of e-learning elements helps the teacher to organize, guide and adjust the independent work of students in the educational process in full-time, these include: electronic materials that support the theoretical course of the discipline; tasks for independent work in electronic form; guidelines for the implementation of tasks for independent work, developed in electronic form.

All materials created for ELC (e-learning course) are available through the local network of the university (computer class), through the educational website of the department or institution, e-mail or social networks.

The complex of the developed software products should not only provide students with theoretical and practical materials, but also to perform the main tasks of training: development of skills for solving practical problems and control the assimilation of knowledge. All this leads to the need to develop complexes of ELC, creating a virtual educational environment with elements of interactive dialogue and personal monitoring, providing students with free choice, both the sequence and the level of depth of the studied material. It is expedient and effective to have a testing system in the ELC which allows the teacher to control the educational group level at each stage of the educational process.

The ELC must meet the following requirements [2]: the content must correspond to the level of modern education; the volume and depth of presentation must correspond to the basic level of knowledge of students; presentation of the studied material has a high degree of clarity. Besides, the ELC format takes into account the capabilities and features of electronic or mobile devices for which it is targeted for.

The requirement of adaptation and activation of independent work of pupils assumes such structure of the textbook at which the user can independently choose sequence and depth of studying of educational material according to its opportunities and preferences. ELC testing system promotes active work of students with the textbook and allows you to adjust your knowledge and skills at each stage of the educational process.

The latter requirement involves the creation of a software shell of the ELC, which should be easy enough to use, so that the teacher can develop and edit on its basis its electronic training course and taking into account the features of the electronic device used.

In this work, you can use the available freely distributed shell (platform), such as Math-Bridge, Moodle, Drupal, Blackboard, and SAKAI.

The description of the intellectual training system Math-Bridge, used as a tool platform for informatization of mathematical courses is devoted to the work [17], and the research in the field of development of electronic testing using the tool environment Moodle and the text editor LATEX is carried out in the work [11]. The paper [10] describes the advantages and disadvantages of such platforms as Blackboard, Math-Bridge, Geo Gebra and Learning Space, which the authors call e-learning-systems, and provide recommendations for their use in the educational process.

All of the above platforms have their limitations. Moreover, for mathematical disciplines associated with a large number of formulas imported into the text, they are often unsuitable or very difficult to use, such as the Math-Bridge platform.

Researchers [6] in the development of ELC based on the SAKAI platform faced with the limited capabilities of this platform: it is a "imposed" and not very successful design, creating difficulties and inconveniences when "reading" the material on the screen; the inability to create an electronic course of the discipline, the sections of which are connected with interface elements that allow to carry out their individual way of its study; difficulties arising in the testing system of the platform, both when editing it by the teacher and during the testing session; the need to develop the website of the educational institution for the introduction of elements of the platform administration. The development of such a site on the Drupal platform with sections of the administrator, teacher and student is described in [7,8].

The development of the original shell (template), made on the basis of its own tool environment, taking into account all the needs and features, as well as the specifics of the course of the discipline, is more popular and effective in the university. E-learning, summarizing the author's long-term experience of using the elements of distance learning in the full-time educational process, for e-learning are demonstrated by the example of e-learning "English grammar" and "Mathematics", performed and successfully used in the St. Petersburg state Marine Technical University

and the Mozhaisky Military Space Academy.

### III. E-LEARNING COURSE “ENGLISH GRAMMAR”

#### A. *E-learning course tool environment*

The tool environment developed by the authors is designed to create electronic textbooks and electronic training complexes on the basis of two shells (templates). The first template - ELC “English Grammar” is made and used to improve the effectiveness of the active form of knowledge of the English language students. On the basis of the second shell – ELC “Mathematics” simulated a stream of modules (sections) of the studied mathematical disciplines to manage independent work of students.

Both shells are original, executed independently from each other, but decided to use the same languages for web programming:

- CSS - a language for describing styles;
- HTML - hypertext markup language, which is used in documents for the Internet;
- Java Script is a scripting language.

The tools used in both shells allow you to open them under any browser, on any wired (computer) or wireless (tablet, smartphone) network electronic device with a minimum set of requirements and in any operating system. The software products developed in the tool environment of the created templates have a fairly small volume, do not require large memory and can be downloaded to any electronic device if necessary.

The existing differences in the structure and interface of the two shells (templates) are due to the specifics of the disciplines for which they are created, and the goal of training. Therefore, the applications of ELC “English Grammar” and ELC “Mathematics” made on their basis significantly differ. If all the information in the English Grammar is provided in the form of text, the mathematical information contains a large number of formulas and is structured in the form of definitions, theorems, proofs of theorems, as well as illustrating the theory of examples. Therefore, the ECU "Integral calculus of functions of one variable" is more widely used Java Script language, which allows you to open auxiliary information as necessary by pressing the appropriate buttons, and for the convenience of reading the text on the screen and free navigation through the pages of the ECU is used two-way placement.

Both shells (templates) are open-source programs [16], which allow both a teacher and a student to create and edit various documents in their environment. Training applications developed on the basis of these shells are web documents that meet the basic principles of convenience (usability), which are described in detail in [20]. Nowadays a lot of papers [1,2,3,21] are dedicated to the development of software applications based on usability principles:

- conciseness and capacity of the text;

- uniformity of the main terms;
- awareness of the system at every step;
- matching the text and format of the device for which it is intended.

The first requirement of usability calls to get rid of redundancy, both in the text and in the design elements, to bring the text in line with the format used, to strive to present the content of educational material and the form of its presentation as a whole. This requirement is met if the text is broken into small “pieces”, and as a unit of text is selected one web page, placed on one screen without additional scrolling. This format of presentation of educational material makes viewing pages of an e-book similar to reading a textbook on paper, in which the pages of the textbook are flipped, rather than unfolding a long scroll rolled into a tube.

Fulfilled the second requirement provides free navigation throughout the study material, allows the introduction of hyperlinks, tooltips and implementation of the electronic textbook search engine.

The third requirement, the so-called “user-friendly” interface, means a good visualization of the structure of the educational complex and the possibility of free navigation through its sections and pages, understandable without learning any instructions for use. The learner should be able to easily navigate from any page of the textbook to any other page using a set of recognizable buttons and links, as well as to understand where the information he needs is located, and what page of the textbook is currently being viewed.

The latter requirement means taking into account all the technical capabilities of the electronic or mobile device for which the application is developed: the size and resolution of its screen, the principle of access to electronic materials, the size of RAM, etc.

Developed on the basis of the ELC shell (template), in which the known methodological requirements for educational material are combined with the requirements for them as software products, create a virtual educational environment through the Internet with elements of interactive dialogue and control.

The developed software products can be used in the classroom in the computer class (if possible) or using mobile devices, which has the vast majority of modern students, as well as in the remote access system on the home computer.

#### B. *E-learning course “English Grammar”*

Template ELC “English Grammar” should be well deducted.

In order to provide information and methodological support for the teaching process of “English Grammar”, a tool environment (template), namely IE software package has been developed [19], which includes the following

modules:

- “ELC” - a program for viewing and studying e-learning courses (for teachers and students);
- “Testing” - a program to perform electronic educational tests (for teachers and students);
- “ELC editor” - a program for creating and editing e-learning courses (for teachers);
- “Test editor” - a program for creating and editing electronic educational tests (for teachers).

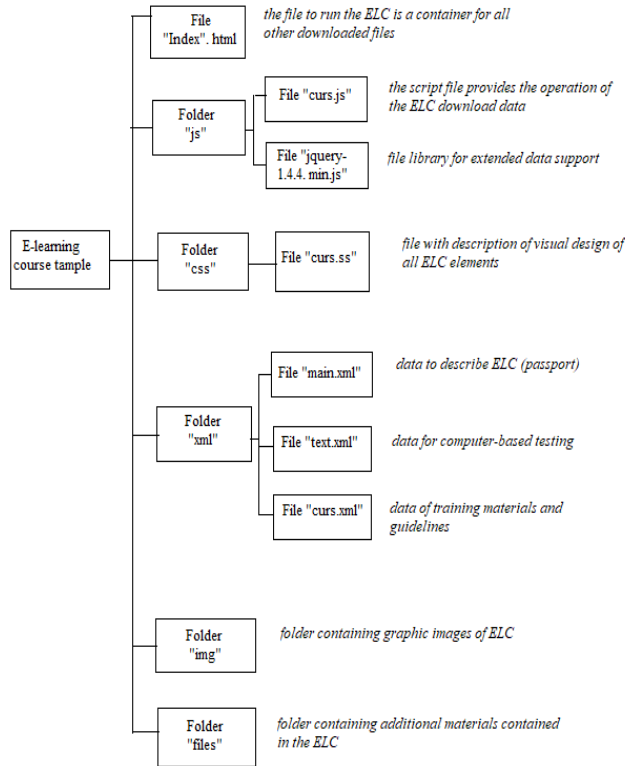


Fig. 1. Elements of the ELC template structure

The structure of the ELC template is a number of elements that perform certain functions and form a single system (Fig.1.). File “index.html” (the startup file is a container for all other downloadable items); folder “js” (file of program code that provides job ELC); folder “css” (a file with the description of the style sheets that define the visual design ELC); folder “xml” (the content files ELC - teaching materials); the folder “img” (file of graphic images) and the folder “files” (additional files: presentations, documents, multimedia, etc., used in ELC).

The ELC tool environment uses the HTML web markup language, CSS cascading style sheets, and Java Script scripting language to run it under any browser, on any local or network electronic device, and on any operating system without the need to install any plug-ins, extensions, or interpreters. When placed on the Internet, the task is facilitated by the absence of requirements for mandatory

support of PHP and MySQL on the server.

The developed shell (template) contains “open source” and allows you to create electronic textbooks on any training course on its basis, having carried out the appropriate editing. Moreover, you can change the design, interface and content of training materials already created training courses, as well as simulate new tests in accordance with the requirements of the time.

The interface of the e-learning course should be arranged so that the student can understand it intuitively. In addition, the interface of the training system should ensure the implementation of an adaptive approach to the organization of training management, i.e. “adapt” to the student and / or the contingent of the training group.

ELC “user-friendly” interface allows going to the relevant section of the training course and return to the list. The student can work with an electronic training course in any convenient sequence, choosing a rational way of studying the material.

The menu contains five items:

Introduction - describes the main goals and objectives set by the authors and solved with the help of this application.

1st Course Theory - contains the main topics of the 1st course, where the basic grammatical information presented in the form of tables, classification lists, etc.

2nd Course Theory - contains the main topics of the 2nd course, where the basic grammatical information presented in the form of tables, classification lists, etc.

Application - A set of applications is a reference book containing the main categories of English grammar.

Testing - contains tests on individual topics and the final program of 1 and 2 courses in different modes of testing.

The test sets out some of the control points of the knowledge test, if the learner (with self-preparation) takes place successfully, the educational system does not intervene if a checkpoint fails, the ELC takes control, encouraging the student to read the corresponding control point of this teaching material [14]. There are 13 tests on the topics of 1 course and 17 tests on the topics of the second course, including the final tests for 1 and 2 courses.

After selecting a test from the proposed list, you can log in to the test system from its start page. In each test session, the student is alternately offered questions from 10 PCs. (one section) to 90 PCs. (final test). The test taker should mark one of the answers and confirm the task execution. The program counts the answer and displays the following question (Fig.2.).

The result - the percentage of correct answers and evaluation - is announced after the full test. With weak results, the student is invited to repeat the theory on the topics on which the questions were made mistakes on the



screen there is a link “Repeat the theory!”

The process of learning a foreign language at the university covers 5 years. The method of improving the quality of mastering a foreign language with the use of ELC includes working out all four types of speech activity: writing, speaking, listening and reading.

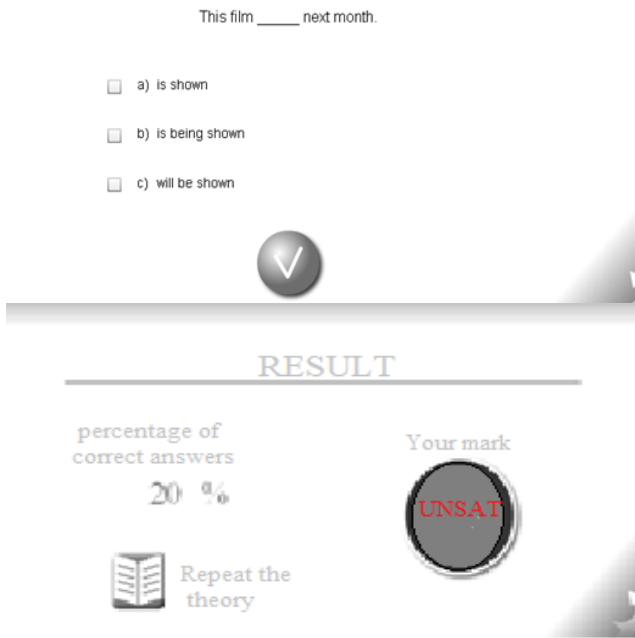


Fig. 2. Question and result of the test session

With the help of checking reading skills and understanding the content of the text read, the quality of mastering a foreign language of students at the end of each year of study was monitored.

Students in the test were offered a text with the tasks contained in the ELC, to understand the meaning of the read, the time to perform the tasks of the test constantly, while the volume of texts and the number of tasks to them increases from 1st year to the 5<sup>th</sup> one. In the first year for the successful passage of the reading skill test students had to read the original text with a total volume of 600 words and perform 8 tasks to understand its content, at the end of the fifth year graduates were offered a 1400 words text and 16 tasks to make (Tab.1.).

TABLE I. CRITERIA FOR THE FINAL TEST OF READING SKILLS USING ELC

Year of study	The amount of text to read with tasks to check the understanding of the content	Number of tasks to check understanding of the content	Total time to complete tasks
I	600 words	8	60 min
II	800 words	10	60 min
III	1000 words	12	60 min
IV	1200 words	14	60 min
V	1400 words	16	60 min

As a result of the final test of reading skills, the average score of students in 2009 - 2014 years of training in the control group was 3.6 points, and in the experimental group - 4.4 points. The average score of students in the control group 2010 - 2015 years of training was 3.8 points, and in the experimental group - 4.8 points.

#### IV. ELC “MATHEMATICS”

##### A. Instrumental environment and structure of ELC “Mathematics”

The shell (template) for creating applications in the form of HTML-documents intended for mathematical disciplines was developed by the authors using the following tools:

- HTML-hypertext markup language, i.e. the language of web-pages creation;
- CSS-cascading style sheets (Cascading Style Sheets), allowing you to control the appearance of the content of web-pages;
- Java Script is a scripting language designed to make web pages interactive.

ELC Mathematics is a flood of applications (e-books), created in the developed layer (template) relevant studied in high school mathematics or areas of mathematics, such as:

- linear algebra;
- analytical geometry;
- differential calculus of functions of one variable;
- differential calculus of functions of several variables;
- integral calculus of functions of one variable;
- differential equation;
- integral calculus of several variable functions;
- ranges;
- theory of functions of a complex variable;
- operational calculus;
- probability theory and mathematical statistics.

The “Mathematics” ELC template is provided to teachers in the form of an open source program [16]. Import of mathematical formulas in electronic textbooks was carried out with the help of photoshop graphics editor, as well as HTML Help Workshop tools.

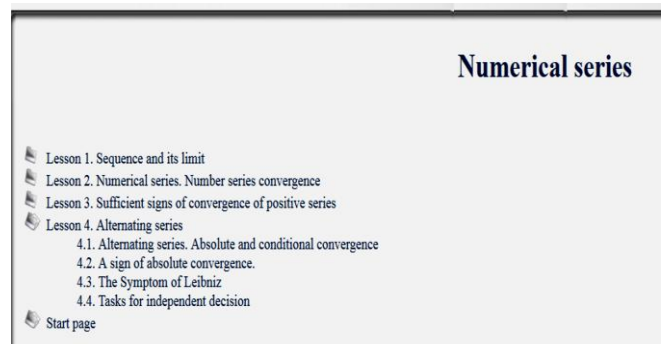


Fig. 3. The main menu of the electronic textbook

For the user (trainee) the application (electronic textbook) is provided in compiled form and is available for reading after clicking on the corresponding button. After entering the application opens the main two-level menu of the discipline or discipline section (Fig.3.), which is divided into modules (classes), and as a unit of employment selected one web-page (screen). Through the main menu you can go to any page of any lesson.

**B. Interface and template design ELC “Mathematics”**

Figure 4 shows the screen view of one web page of the lesson being studied. On the left side of the screen there is a menu of its web-pages, as well as a button to go to the list of activities.

The view of the lesson screen is designed so that the textbook can be studied at two levels: theory in preparation for exams; practical problem solving skills in homework or preparation for test work. In order to open the screen and highlighted the bright color of the core information: definitions, theorems, comments. Additional information: proofs of theorems, examples illustrating the theoretical material, etc. are opened and closed, if necessary, by corresponding buttons.

1. Numerical series	
Content	Lesson 1. Sequence and its limit
<ul style="list-style-type: none"> <li>Lesson 1. Sequence and its limit</li> <li>1.1. Separating</li> <li>1.2. Properties of sequences</li> <li>1.3. The limit of a sequence</li> <li>List of lessons on the course "Number series"</li> </ul>	<p style="text-align: center;"><b>1.3. The limit of a sequence</b></p> <p><b>Definition 1</b></p> <p>The number <math>A</math> is called the limit of the sequence when <math>\{x_n\}_{n \in \mathbb{N}}</math>, if <math>\forall \varepsilon &gt; 0</math> there is such a number <math>N</math>, that for all <math>n &gt; N</math> is performed <math> x_n - A  &lt; \varepsilon</math>. This is recorded as:</p> $\lim_{n \rightarrow \infty} x_n = A$ <p><b>Definition 2</b></p> <p>A sequence that has a finite limit is called convergent.</p> <p><b>Example 1 (+)</b></p> <p><b>Example 2 (+)</b></p> <p><b>Example 3 (+)</b></p> <p><b>Example 4</b></p> <p>The sequence given by the formula <math>n</math>-th term <math>x_n = 3 + (-1)^n</math> has no limit, either finite or infinite, since for any <math>n</math> its members are 2 or 4.</p> <p><b>Weierstran Theorem</b></p> <p>Every monotone sequence has a limit. This limit is finite if the sequence increases and is bounded from above, or if it decreases and is bounded from below.</p>

Fig. 4. E-textbook view window

**C. Section of personal monitoring template ELC “Mathematics”**

The personal monitoring section of the shell includes both a set of tasks for self-help with answers placed at the end of each lesson (Fig.5.) and testing system. A set of tasks for self-solution with answers, and sometimes with tips, is not only an element of self – control, but also solves an important problem of learning-helps to consolidate the studied material.

The system of testing of ELC “Mathematics” includes a set of control tests on all topics of the electronic textbook and is intended for self-testing of the level of knowledge on the studied material and carrying out control actions by the teacher. Test tasks are developed in the form of tasks with

the choice of the correct answer from several presented. The set of tasks of each test covers all the material of the topic to be learned. The ELC “Mathematics” is adapted for use both on the computer and in the mobile application [3,9,22].

1. Numerical series	
Content	Lesson 2. Numerical series. Number series convergence
<ul style="list-style-type: none"> <li>Lesson 2. Numerical series. Number series convergence</li> <li>2.1. Numerical series. Convergent number series</li> <li>2.2. A necessary sign of convergence</li> <li>2.3. Properties of converging series</li> <li>2.4. Tasks for independent decision</li> <li>List of lessons on the course "Number series"</li> </ul>	<p style="text-align: center;"><b>2.4. Tasks for independent decision</b></p> <p><b>Task 1</b></p> <p>Investigate the convergence of a number series <math>\sum_{n=1}^{\infty} \frac{2n+3}{5n-1}</math></p> <p><b>Answer</b></p> <p>The series diverges.</p> <p><b>Tip</b></p> <p>Use the corollary of the required trait.</p> <p><b>Task 2 (+)</b></p> <p><b>Task 3 (+)</b></p> <p><b>Task 4 (+)</b></p>

Fig. 5. Tasks for independent decision for the studied occupation

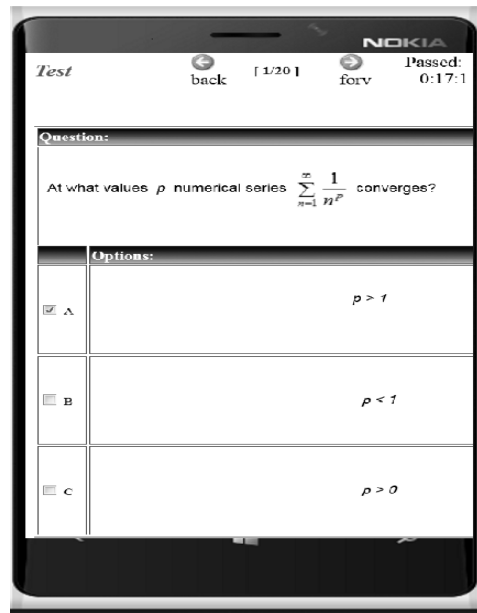


Fig. 6. Test task screen

During the test session, you can freely navigate through the questions, i.e. you can return to the previous questions with the “Forward” and “Back” buttons, which are colored when clicked. The screen displays the number of tasks in the task, the number of the task that is viewed on the screen, as well as the time counter (Fig.6.). These attributes allow you to control the test session.

When announcing the results are included: the number of correctly solved problems, rating, evaluation, as well as the names of those sections of the training course (Fig.7.), which are recommended to work again. The list of these sections is made in the form of hyperlinks, which you can immediately go to the desired page of the ELC.

At the top of each view screen (Fig.7.) there is an interface element, on hyperlinks of which you can go to the main menu of the tutorial, to the topic on which the test session is conducted, and re-enter the test.

Numeric and functional series > 5.1. Test: Numeric and functional series

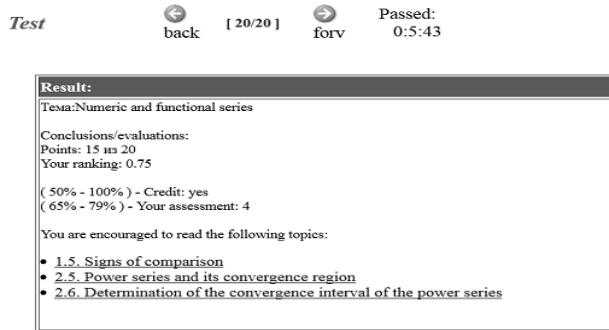


Fig. 7. Announcement of results

#### D. Testing system for current and final control

ELC with a testing system, within which preliminary and final testing is carried out, are described in [1,21]. In ELC “Mathematics” it is possible to conduct both current and final control of the training group by the teacher.

Adaptation of educational electronic applications for a mobile platform, the so-called adaptive programming, is currently a very relevant research topic, so the creation of mobile web applications based on new versions of HTML and CSS languages – HTML5 and CSS3 is described in detail in [4], and the work [13] is devoted to the principles of developing a “mobile design strategy and text preparation for miniature screens”.

It should be noted that the test program is designed so that for a test session, one option for the entire academic group is enough, since each time you enter the test, the tasks and answer options are mixed, so that the “neighbor” option becomes “unrecognizable”.

Since the announcement of the results (Fig.8.) included not only the rating and the exposed assessment, but also the list of occupations on which materials mistakes are made, the teacher can correct process of training on the basis of results of testing.

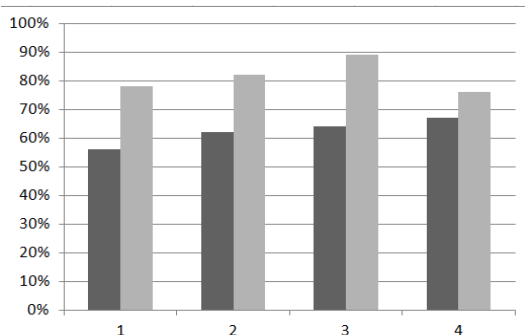


Fig. 8. Comparative analysis of exam results

Conducting current and final control in the form of testing using ELC significantly improves the quality of training. The “inevitability” of constant monitoring, which takes a small amount of time, motivates students to work actively. After the control in the form of a test, there is the appearance of specific questions to the teacher instead of vague complaints – “I do not understand anything”.

Current and final testing using ELC has been carried out in Spbgmtu since 2001, as well as a comparative analysis of academic performance (in percent of those who passed the exam on the first attempt) of study groups trained using ELC (experimental groups) and study groups trained without the use of ELC (control groups).

Results of the comparative analysis of success of training of four groups of faculty of target and contract preparation-experimental groups-during a semester (row 2), and four groups of faculty of marine instrument – control groups – (row 1), given in the diagram Fig.8, confirm the effectiveness of the application developed by the authors of the ELC “Mathematics”.

#### V. SUMMARY

The method of learning a foreign language with the help of ELC forms and improves the students' knowledge of lexical and grammatical phenomena and terminology, contributes to the mastery of all types of speech activity. ELC enables students to work at their own pace and develop their own individual trajectory of learning and self-control of lexical material, which at the senior courses incomparably exceeds the volume of vocabulary in the first years of training.

Since the ELC consists of training modules, it is aimed at the formation of various skills and abilities, carrying out this with the help of an algorithmic approach based on the description of the process of solving semantic problems by students, the creation of appropriate algorithms and the transfer of ELC control of the process of their solution in the form of test tasks on the material, applications with auxiliary information.

Thanks to ELC students spend as much time at the computer as they need to learn this topic, having the opportunity to repeatedly refer to the theoretical and test blocks. ELC can significantly increase the development of practical skills and is a valuable tool for those students who for any reason missed classes. The ELC learning system implements elements of an adaptive approach to the organization of learning management, i.e. provides the ability to select the order and intensity of the study of the material on the basis of the results achieved by the learner.

The quality of students' education is improved through the combination of information and pedagogical technologies in the educational process and the use of electronic and mobile devices. Well-methodically developed and easy-to-use electronic resources: electronic textbooks, mobile applications, etc. are a platform for the development of a digital educational environment that “accompanies” the

student in his independent work, contributes to the systematization of his knowledge, obtaining skills to solve practical problems, the ability to independently identify and correct errors in their decisions.

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